Analytical Tools for Evaluating the Water Supply, Hydrodynamic, and Hydropower Effects of the Bay-Delta Plan

Invited Panel: Jay Lund (Chair), Jon Burau, John DeGeorge, John Durand, Greg Gartrell, Marianne Guerin, Pete Smith, William Smith, Mark Stacy
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"The purpose of computing is insight, not numbers." Richard Hamming (1962

The growing complexity of water and environmental management has led to the need to use formal quantitative models of water and environmental systems. These models attempt to provide reasoned insights into the behavior and impacts of these systems under a variety of conditions, operations, and policy alternatives, based on what is known about these systems. As such, computer models, if properly employed, should generally be able to provide guidance for management which integrates a wider range of scientific information than would be possible using experience or educated intuition alone.

For Bay-Delta policy, planning, and management discussions in California, including the various Bay-Delta Plans, the State Water Resources Control Board (Board) will need to evaluate and explore water supply, hydrodynamic, and hydropower effects, as well as various ecological, water quality, and economic effects of many alternatives over a range of conditions. For such a complex system, this will require the use of a variety of computer models, and the interpretation of their results.

This report is intended as a basis for discussion at the third Board workshop held as part of the comprehensive review and update of their Bay-Delta Plan. It begins with the panel's charge, followed by some framing comments, near-term recommendations, and recommendations on preparing for the future.

Charge

The panel's charge from the State Water Board was to synthesize current scientific knowledge regarding:

"Analytical Tools for Evaluating the Water Supply, Hydrodynamic, and Hydropower Effects of the Bay-Delta Plan – including the CalSim II water supply model, DSM2 and RMA2 hydrodynamic models, Plexus hydropower model, and others as applicable, together with results from applying these models to various scenarios. "

The panel was asked to identify major points that the Board should be considering on this topic. Specific questions were:

1. "What types of analyses should be completed to estimate water supply, hydrodynamic, and hydropower effects of potential changes to the Bay-Delta Plan?
2. What analytical tools should be used to evaluate these effects? What are the advantages, disadvantages, and limitations of these tools?"

Based on a Staff Report (2009) to the Board, potential changes to the Bay-Delta Plan recommended for review in the water quality control planning process include:

- Delta Outflow Objectives
- Export/Inflow Objectives
- Delta Cross Channel Gate Closure Objectives
- Suisun Marsh Objectives
- Reverse Flow Objectives (Old and Middle River Flow Objectives)
- Southern Delta Salinity Objectives
- San Joaquin River Flow Objectives
- Floodplain Habitat Flow Objectives
- Changes to the Monitoring and Special Studies Program
- Other Changes to the Program of Implementation

Given the short time available to the panel and the Board's need for conciseness, we have divided our comments and recommendations into three areas, 1) Framing comments, 2) Near-term recommendations, and 3) Preparing for the future. The panel addresses the Board's specific questions in a more general manner, to provide some more strategic guidance on what will likely become a host of detailed modeling questions.

Framing comments

As stated in the preamble, the major value of computer models is not numbers, but in providing insights. Anyone familiar with quantitative analysis from home budgets, retirement investment calculations, home remodeling estimates, or state budgeting, knows that quantitative analysis is approximate, but indispensable to thoughtful, reasoned decision-making.

1. Models do not stand alone. Policy-makers often ask, "Is X a good model?" Three components influence the quality of results from a model study: 1) the model itself, including software, calculations, and parameter values, 2) the input data entered into the model, and 3) the modeler, who selects the model, prepares and scrutinizes the input data, and interprets results from the model's calculations. Of these, the human modeler, who has an understanding of the problem, the data, and model software and methods, has the greatest responsibility for model results.

All three of these modeling components typically represent an integration of diverse forms of knowledge and data regarding a complex problem. Together, if properly managed, they can provide far greater insights into problems and solutions than any component alone. To make modeling effective, computational results must be combined with thoughtful data analysis and results comparison, evaluation, and interpretation in the context of expert knowledge of the system and the problem being considered.

2. Different models for different problems. No single model is best for all conditions and problems. All models include various assumptions, which for Delta hydrodynamic models include the coarseness and dimensions of geometric representation, treatment of density (as constant or variable), choice of gate equations and friction law, turbulence formulation, treatment of open-water bodies and Delta Island Consumptive Use and return flows (DICU), etc.

Of the one, two and three dimensional models available for the Delta, most general hydrodynamic and water quality modeling for near-term Bay-Delta plans can be accomplished with one or two dimensional (1-D and 2-D) models. Presently, DSM2 and RMA2 are the two hydrodynamic models most widely used. However, if the Board requires model studies involving island levee breaches, sea level rise, fine-scale hydrodynamics of junction flows, sometimes new restored habitats, or even detailed analysis of salinity in Suisun Bay during the fall, a three-dimensional (3-D), tidally-variable hydrodynamic and transport model may be needed. Even for these cases, it may be more practical to simulate the position of the estuary's salt field across many years using a 1-D or 2-D model calibrated to 3-D model results, because a three-dimensional model may be computationally prohibitive for long periods of analysis.

All models, hydrodynamic and otherwise, include empirical parameters that require calibration to field conditions. When the conditions being simulated are far from the range of field data used for model development and testing, or are future predictions for planning purposes, then the model's application becomes increasingly tenuous, although greater adherence to detailed physical representations can be helpful.

For complex problems with few data or long modeling horizons, a simple model is often as accurate, and more insightful, than a complex model. A clear problem statement must be judiciously matched to a choice of model, with consideration of the spatial scale of the problem, the dimensionality of the processes, the conditions and timescales being considered.

3. Models summarize understanding. Models are attempts to integrate our understanding of complex processes into a workable form that can provide insights for policy and management deliberations, as well as for scientific investigations. In addition to providing a way to standardize the evaluation and exploration of solutions to complex problems, models are also important for integrating the accumulation of science needed for effective adaptive management (Hollings 1978).

Near-term recommendations

This section recommends a more systematic approach for a Board (which primarily assembles information by written and oral testimony) to vet and scrutinize the diverse types and uses of modeling results likely to be encountered regarding Bay-Delta issues. Some gaps and areas of concern for models applied to the Bay-Delta planning are summarized in Appendix 1.

Keys to Bringing Analytical Results to Policy-making

- Education - so policy-makers can better absorb and deliberate on results
- Documentation and testing - to add transparency and provide basic technical quality assurance
- Technical reflection - to provide a disinterested technical perspective and timely response to questions
- Coordination - to reduce effort and expense, consolidate knowledge, and reduce overload of policy-makers
- Communication – passing concise insights to managers and decision-makers, with technical documentation readily available

4. Understanding "how the Delta works." The complex dynamics of the Delta are a mystery to most, even many long-timers. Visualizations of field observations and modeling results, with concise explanatory narratives, can give policy-relevant insights on key Delta features, such as tidal flows, salinity and turbidity distributions, sources of contaminants and other water quality constituents, or habitat behavior. These are useful in developing insights into the nature of the Delta. We recommend that a fundamental set of visualizations of Delta processes be assembled with brief explanatory text and references on "How the Delta Works," and that these be made available as a web site and short course. Such a resource would help raise the common level of understanding of this often mysterious system.

5. Existing hydrodynamics, operations, planning, power, and economics models can provide insights and information, but must be documented and interpreted more thoughtfully and critically for each application. To assess the applicability and utility of these types of models for the proposed purposes, thoughtful and critical documentation of the models is needed. General documentation and testing should be readily available prior to the use of the model so that 1) the best model is chosen for the stated problem and 2) the model and results are used correctly. For each application, proper documentation ensures that new insights are gained not just for the problem at hand, but also for future applications and improvement of the model. New insights on the model become part of a growing documentation for the problem and the model to aid future model applications and overall improvement of modeling capability.

6. Models and model results used in Board proceedings should be better documented and include a discussion of the strengths, weaknesses, and limitations for each application. Understanding and transparency come largely from adequate and thoughtful documentation and testing of a model and model results (Konikow and Bredehoeft 1992). Only when model results are interpreted in the context of model strengths, weaknesses and limitations for a particular problem can reliable insights be gained.

Model strengths can include the model's ability to reproduce field data at relevant locations for a wide range of conditions. Such testing suggests where the model is well calibrated, where it adequately captures the physical processes and whether it can robustly simulate those processes. Documentation of model testing for conditions relevant to the problem gives the model and modelers credibility. Conversely, failure to provide sufficient details on model strengths and weaknesses should be seen as a sign of model weakness.

Model weaknesses can include major differences of results from field data, including an assessment of the causes of these discrepancies. All models will fail to some degree to reproduce field data for reasons that include inaccurate field data, inaccurate boundary conditions (for example, Delta inflows or in-Delta diversions and returns may be poorly known), model calibration, inability to represent an important process (such as turbulent diffusion), or simplifications required for the model. (Models also can fit well for the wrong reasons in calibration, and then perform poorly.) Knowledge of model weaknesses allows for better interpretations of results. For example, documentation describing the degree to which a salinity model is inaccurate at one location compared to field data, even though it may be relatively accurate at other locations, helps in interpreting and assessing model results. Such an assessment is not possible, however, if weaknesses are not revealed, discussed, and documented. A model with no documented or discussed weaknesses should be considered to be a questionable and likely weak model.

All models have limitations, and these should be discussed with respect to the interpretation of model results for a particular purpose or problem. Use of a model outside the limits of tested field conditions (for example, for inflow conditions that have never existed, or with major new physical features beyond calibrated and tested conditions) requires alternative forms of testing and a more cautious interpretation of results. However, for many routine problems, model results can be quite reliable and interpretation can be based on prior model testing.

In some cases, limitations are absolute and use of the model would be invalid outside of those limits. For example, a flow-salinity relationship based on recent data would not be valid to determine the flow needed to attain a given salinity under future conditions with significant sea level rise. A one-dimensional model might provide some insight for this problem, but the uncertainty would be larger than with a well calibrated (but more computationally expensive) two or three dimensional model.

Documentation of model limitations is essential to interpretation and communication of model results for a particular problem.

Some Key Aspects in Calibrating and Testing a Delta Hydrodynamics Model
In the testing and calibration of a Delta hydrodynamic and water quality model, the panel suggests several key aspects to examine. These include:

- Matching point observations of Stage, Flow, Salinity (EC) on tidal and tidally averaged (net) basis
- Matching key interior net-flow splits: Sacramento River to Sutter and Steamboat Sloughs; Sacramento River to Delta Cross Channel and Georgianna Slough; San Joaquin River to Old River at Head; San Joquin River to Old River and Middle River; net flows around Franks Tract; flow between the Sacramento River and San Joaquin through Threemile Slough
- Representing gate/barrier operations: DCC, Suisun Marsh Salinity Control Gate, south Delta barriers, Clifton Court Gates
- Representing Delta Island Consumptive Use
- Representing Delta Exports
- Representing low flow, high flow, and transition periods
- Representing the yearly cycle of salt intrusion and flushing
- Representing spring-neap tidal variation

7. Clearer statements of desired Delta states are needed before analyzing implications and possible implementation solutions – What are we looking for? Modeling supports Delta management decision making in two important ways. One is in exploring how to achieve an "in-Delta" objective. The second use is to assess impacts of a particular management alternative under a particular set of conditions, which often leads to additional exploration.

Some examples of exploratory modeling might include evaluating the use of operable gates for desired flow splits, adjusting Delta export pumping with net flows, or exploring tidal marsh restoration configurations to optimize key habitat characteristics. In each case it is essential to identify a few key metrics that differentiate better from worse alternatives. For ecosystem objectives, this is particularly challenging and essential.

Some examples of model use to assess ramifications of a management alternative include evaluating Delta-wide impacts on tidal range due to local tidal marsh restoration, or assessing water supply implications of in-Delta flow requirements. With this type of modeling, the emphasis moves toward longer time scales and the ability to meet a local objective through system-wide operation. A key challenge is to ensure that all major implications of a management alternative are included in the analysis. For example, flow requirements for in-Delta fish habitat that lead to reservoir operation changes may affect cold water pools in upstream reservoirs, which affect upstream riverine fish habitat.

Developing clear statements of desired states for a management objective are essential in selecting appropriate models defining the modeling analysis. Identification of metrics, management options, and larger system linkages will determine the types of models, spatial and temporal resolution, analysis period, and output requirements for a problem-oriented model application. In exploring alternatives, defining objectives and modeling are often a cyclical learning process.

The importance of stated objectives: Which models are relevant for X2?

Scientists and modelers encourage the Board to make clear statements of desired objectives for the Delta to better focus science and modeling analysis. Modelers and scientists can then choose analytical tools and organize studies that simulate or optimize the physical, chemical, and biological processes related to that objective. For example, if maintaining the position of the 2 part per thousand isohaline (X2) at a particular location in Suisun Bay protects fish communities by keeping them away from Delta diversion and pumps, then a one-dimensional hydrodynamics model is useful because it can easily explore a range of conditions. However, if fish communities benefit from the *area* of low salinity habitat and proximity to habitat like shoals or wetlands, then a two-dimensional hydrodynamics model may be needed to describe low salinity zone area and dynamics. Or, if fish communities respond to gravitational currents, or vertical gradients of salinity or water velocity, then three dimensional models should be applied. The Board should not necessarily ask which models are best. Instead, the Board should require skilled scientists and modelers to work together to choose analytical tools and application strategies to clarify alternatives, costs, and implications for beneficial uses and explain this analytical reasoning.

8. The Board can more effectively use computer modeling and modeling results to inform policy decisions by seeking input from independent modeling experts. We suggest:

a) Strategically, establish a group of independent modeling experts to assist the Board in broadly assessing modeling for Delta problems and help establish policies that improve the contributions of modeling to Board activities and deliberations.
b) To better incorporate and evaluate modeling testimony to the Board, establish a group of experienced disinterested technical experts to concisely assess the quality and accuracy of model applications presented to the Board in a policy-oriented context.
c) Encourage groups of stakeholders to present more consolidated, organized, and documented sets of modeling results and syntheses relevant to Delta problems.

Skillful use of models and interpreting of model results in a complicated physical system, such as the Sacramento-San Joaquin Delta or its upstream watersheds, requires a significant investment in training and years of experience. The implications of SWRCB decisions are often far-reaching and entail significant investment of Board members and staff, as well as those offering testimony and comment. Organized advice from highly competent internal and independent groups can help ensure that model development and applications used in Board deliberations are well evaluated and considered for Board purposes.

Establishment of a formal group of independent experts who can commit to service for a reasonable period of time, with periodic additions or changes in the composition of the group, would allow for continuity and retention of collective insights while providing for new perspectives over the longer term. Such a group could help reduce the “noise level” of information provided to the Board and the community and help establish a culture of continuous improvement.

Requiring groups to provide documentation regarding model results will allow experts and the Board to to reflect on the work and assess its quality (per Point 6).

9. A state strategic modeling plan is needed for the Delta, preferably based on a "community development" approach. California collects much data which is underutilized, and does not collect some data which would often be more valuable. The state of California and the federal government also invest in developing many water-related models, often with little coordination among agencies and no synergy between groups developing new models. In some cases, models are not widely available (e.g., are proprietary) or lack proper documentation and testing.

A strategic modeling plan is needed that better addresses major current and projected needs for California into the future, as serious model development typically requires years of well-managed effort. Some model applications need data to better represent some areas – such as Suisun Bay and Marsh – while other model applications are missing categories of measurements – such as lack of data on nutrient interactions with sediments. Hydrodynamics and water quality data are available for many models, but much of this data has not been through a quality control (QA/QC) step to assure accuracy. Individual modeling groups currently develop in-house data sets, with avoidable duplication of effort and inefficient use of scarce funds and expertise. A state-led effort that engages with the modeling community to define data acquisition needs, to maintain and QA critical data sets and to provide data access will save money and increase consistency in applications. Similarly, ongoing model development would benefit from a "community-based" approach – where state agencies would work together and with the larger modeling community, including federal agencies, consultants, academia, and research institutions, to establish more common model input and output formats, to develop and distribute more common data analysis software, and to define and champion critical areas for model development.

Preparing for Future (5-15 years)

The development of data and analytical capability takes time and the problems of the Delta in the future will substantially differ from today, driven by geologic and climatic forces, as well as human decisions. To make modeling and analysis more effective in the future, we make several recommendations.

10. Integrating our understanding by integrating our models. The independent development of computer modeling capabilities by different groups and agency departments provides important opportunities for innovation. However, the lack of integration across major models routinely used by the state is an impediment to integrated resource management. For the future, the Board should encourage the integrated development of modeling capability to evaluate desired Delta states, in ecological terms, as well as for water supply, water quality, and flood management. These models should work together and cover some additional areas, such as relatively simple models of water quality and habitat from an ecosystem perspective. Much more focused state leadership will be needed to accomplish this goal, and such model and data development will require involving expertise from a range of disciplines and institutions.

An example of benefits that can come from more multi-disciplinary and integrated modeling is the use of hydrodynamic and water quality modeling to help improve understanding and management for native fishes.

Use of hydrodynamic modeling to better understand fish

Hydrodynamic modeling has been usefully employed in the Delta for over two decades. Ecosystem modeling, including nutrient-phytoplankton-zooplankton and fish life history models, has been much less developed. Nutrient and chlorophyll-a models are better developed. But understanding and representing more complex organisms, such as zooplankton and fish, now relies heavily on inference from circumstantial data. As a result, most deterministic ecological models have less reliability than hydrologic models, and form a weak link in understanding of many ecosystem processes.

This weak link can be addressed in part by ongoing research on organism physiology (such as thermal limits), ontological development (spawning and rearing habitats) and food web interactions (such as the nutritional quality of zooplankton for smelt). However, because of the complexities of ecosystems with diverse organisms, synthesis and inference will likely remain important to understanding hydrodynamic-organism relationships in the foreseeable future. Hydrodynamic models can help reduce uncertainty in key environmental aspects of an organism by providing measures of physical variables related to organism abundance, biomass or fitness (such as flow magnitudes and velocities, turbidity, salinity, temperature, and measures of residence time), to integrate with expert judgment from fish biologists.

Hydrodynamic models are crucial to predicting the effects of restored Delta wetland or flooded island habitats on plankton and fish populations. Restored habitat will not necessarily support desirable estuarine species unless temperatures, turbidity, and flows are appropriate. Food web processes will not function well without appropriate nutrient loads, turbidity and residence times. Hydrodynamic modeling is critical to determining sustainability and promise of proposed restoration projects.

11. Model and data development has become too important to be done in isolation by one agency or group. Efforts to integrate and diversify modeling efforts are needed. Appendix 2 represents initial efforts in such a "community" direction.

The Board is in a good position to encourage the various state, federal, and local entities with business before the Board to develop a more coherent and cooperative technical and scientific basis for providing information and perspectives to the Board, as well as other purposes. In some areas, expectations for more formal model documentation and testing will be sufficient, such as fostering the development of an authoritative hydrodynamic and water quality data set for the Delta for testing models and a set of basic testing metrics (Appendix 2).

In other areas, such as operations planning and policy modeling, the Board faces a major and growing gap. State and local models of water projects (such as CalSim) do not reflect the interactions, operations, and management options (such as conservation, water markets, conjunctive use, and water reuse) that are common locally and regionally, with statewide importance. They also provide too little opportunity for broad technical involvement and integration of information and expertise.

Although Board authority can encourage more efficient and effective "community modeling and data development," the Board is unlikely to have regular funding and management capacity to devote to this subject. A major question is how California's water model and data development community be better organized to produce more transparent and effective modeling capability to explore and evaluate policy and management alternatives. For Delta problems, the Delta Stewardship Council's Science Program or a State and Federal joint venture (possibly involving the Corps of Engineers innovative Hydrologic Engineering Center) might provide suitable venues. The California Water and Environment Modeling Forum (CWEMF.org) can be useful on this issue. Many examples are available of more organized use and development of models, including the climate science community's use of the National Center for Atmospheric Research (NCAR) as a central keeper and disseminator of models and model results and the US Environmental Protection Agency's Center for Exposure Assessment Modeling (CEAM) (http://www.epa.gov/ceampubl/).

12. Major drivers will force major changes in parts of the Delta and Bay. Major forces affecting the Delta include sea level rise, rising temperatures, and other climate changes, additional invasive species, growing Delta and importing-region populations, higher valued state agriculture, changing Delta land uses, land subsidence, shoreline management, restoration, and development, changes in technology, long-term scarcity of state and federal funding, new pesticides, and new drinking and wastewater treatment standards. These many factors will simultaneously contribute to inevitable long-term changes in parts of the Delta. Some events, such as a major earthquake, can make change occur abruptly.

Climate change, and many other changes, can be represented in models, but external climate, flow, and other conditions must be developed and their accuracy cannot be guaranteed for major changes. Our ability to handle climate change is no better or worse than other major changes in the Delta system.

Appendix 1 – Some Key Gaps

The panel lists below some key gaps in some major modeling areas of interest for Delta policy. In the area of multi-dimensional hydrodynamic modeling, in 2009, a diverse group of Delta hydrodynamic and water quality modelers suggested a community-based approach that appears in Appendix 2.

Biological and Ecosystem. The use of biological and ecological models for the Bay-Delta is in its scientific infancy, and has often been abused when employed for policy purposes. Nevertheless, insights often arise from fairly simple models of biological and ecological processes, especially as they relate to physical and flow conditions in some circumstances. Many of these models are conceptual in nature, although some are mathematical and numerical.

A series of conceptual ecological models were developed as part of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). The models provide transparency to the reasoning used to evaluate ecosystem responses to biological or physical changes. While they have received mixed reviews because of their complexity, they are being employed by the Ecosystem Restoration Program (ERP) in vetting restoration projects in the Delta.

Economic models (SWAP, LCPSIM). Models of agricultural water use (such as SWAP – the StateWide Agricultural Production Model) have developed considerably in recent years, enough so that challenges of representing salinity, nitrate, climate and other aspects have become desirable. Models of urban water conservation remain in their infancy statewide, although some state models of urban area water management (LCPSIM) do show how models of water conservation can be integrated with information on other water management options and their costs.

Groundwater and Hydrology (e.g., C2VSIM, CVHM, SimETAW, and others). A wide variety of hydrologic and groundwater flow models are employed for problems ultimately related to the Delta. These are important especially for problems involving water storage, climate change, in-Delta water use, and a variety of issues upstream of the Delta and for water management upstream and in water-importing areas. Groundwater models have been improving steadily in the last decade, but often retain significant uncertainties. Hydrologic models are common for a range of conditions (particularly floods). The major gaps over this broad field are lack of coordination among agency efforts and uneven model documentation and testing.

Hydrodynamics and water quality (e.g., DSM2, RMA, and others). Significant gaps in hydrodynamic and water quality modeling for the Delta and Bay include turbidity, in-Delta consumptive use and return flows, improved Delta gate formulations (particularly for Clifton Court Forebay), updated Suisun Bay bathymetry data, particle tracking improvements, data to calibrate individual-based fish models (IBMs), water temperature in shallow areas, wind field representation and data, wind wave dissipation and dispersion, linkages to ocean and upstream river models, and nutrients (including benthic processes and aquatic vegetation). Additional thoughts are included in Appendix 2 - Improved Modeling Capabilities Needed for the Bay-Delta Planning Effort (2009). Earlier comments on modeling gaps in conveyance modeling are summarized in Science Advisors (2008) and Healey (2008).

Hydropower (e.g., LongTermGen(CVP), SWP Power; see Appendix 3). Most current models of hydropower production and pumping power usage for the Central Valley are post-processors, which estimate the energy production and revenue implications of water operation changes and power values determined by other models, such as CalSim. The major gaps include: only including CVP/SWP facilities, a single value/cost is assigned ignoring power market impacts of operational changes, and other ancillary energy grid service values are not included.

Operations Planning (e.g., CalSim II, CalLite, and others; see Appendix 3). CalSim II is a planning model for SWP and CVP operations. CalLite is a simplified version of CalSim II designed to produce results similar to CalSim II with a shorter run time. The absence of a statewide integrated water management simulation capability has led to CalSim II's use for more general purposes. Other models, such as CALVIN (which emphasizes integrating operations with economics) and WEAP (which emphasizes integrating hydrology and demands), also have been applied for various purposes. Hydropower operations above the foothill water supply reservoirs are significantly guided by the use of proprietary optimization models.

Some key gaps include: testing against field operations and data (although difficult, this can help determine accuracy and set expectations of actual deliveries or flows, which may not be met if the model is inaccurate), groundwater interactions and operations, integration of SWP and CVP project operations with unrepresented local and regional operations statewide, better representation of water demands, overly constrained examinations using current conditions for long-term planning, optimization capability to suggest promising solutions, agricultural return flows, simple reservoir and river temperature representations, absence of representation of the Tulare Basin.

Appendix 2 – Improved Modeling Capabilities Needed for the Bay-Delta Planning Effort (2009)

June 9, 2009

To: Joe Grindstaff, CALFED Director
Clifford Dahm, CALFED Lead Scientist

From: CALFED Hydrodynamics Modeling Community Members

RE: Improved Modeling Capabilities Needed for the Bay-Delta Planning Effort

The Bay-Delta is in transition. Sea level rise, additional flooded islands, more aquatic habitat, and significant changes in water flow and quality will make the Bay-Delta very different in the coming years. Without sufficient modeling capability to predict how water flow and water quality will respond to these changes, we face the likelihood of a less-than-adequate scientific basis for management, planning, and policy decisions. California's water community needs to invest in expanding and updating our hydrodynamic and water quality modeling capabilities and to improve Bay-Delta field measurements. With these objectives in mind, a subset of our group wishes to meet with you and/or your staff to discuss how a targeted work proposal can best be developed for your consideration.

A wide variety of models are currently being used or are under development in the Bay-Delta, including one-dimensional (1-D) models (DSM2, FDM), 1-D/2-D hybrid models (RMA, REALM), 2-D (only) models (TRIM2D), and a suite of 3-D models (TRIM3D, UnTRIM, Si3D, SUNTANS, Delft3d, ROMS). These models provide users a toolbox for solving a variety of problems under a range of conditions. Although significant model improvement has been made recently, not all modeling needs are currently being met, and many expected future conditions will require enhancements to existing tools to ensure proper analysis. Because hydrodynamic and water quality modeling is at the heart of any scientifically-based policy, planning, and management for a changing Bay-Delta, enhanced modeling capability is a high priority. An expanded list of modeling needs is provided in Appendix 1. Given the controversial nature of policy-making in the Bay-Delta, these needs must be met with a high level of scientific transparency, proper verification and validation, adequate documentation, and rigorous peer review.

Two urgent needs should be addressed immediately. We recommend:

- Semi-formal **comparison of model performance** for the DSM2, RMA, TRIM3D, and UnTRIM hydrodynamic models should be performed as soon as possible using general procedures outlined in previous calibration reports (CDWR 2005, 2008). Performance of each model should then be described and discussed when confronting hydrodynamics data collected in 2007 and 2008. The aim of this performance evaluation is not to establish primacy of an individual model, but rather to identify which attributes of each model make it more or less suitable for given applications, and to help document how best to use our suite of models and our community of modeling expertise.

- Immediate investment in a formal program to update, evaluate, and maintain a widely-available **bathymetric and topographic digital elevation dataset** for use regardless of platform or program code. All Delta models and all applications for these models require the most accurate and most recently updated bathymetry with which to resolve system dynamics. Accurate, current bathymetry will benefit not only modeling but also other emergency response, operation, planning, and conservation applications. The updated, maintained grid will also provide the starting point for any evaluation of levee breaks, shoreline protection decisions, island floods, and restoration trajectories within the sub-tidal to supra-tidal Bay-Delta basin under conditions that include seal level rise and flooded Delta islands.

As a necessary follow-on, and to realize a substantial improvement in California's Bay-Delta modeling capabilities, we also propose enhancing future investment in model and data collection and analysis to provide new modeling capabilities and to develop more informed insight into the Delta's problems and potential solutions. A nomination of elements essential for an effective modeling program is listed in Appendix 2.

We share in your enthusiasm for revitalizing the community of Bay-Delta modelers, and we are ready and willing to meet with you to discuss ways for moving support for our efforts forward, particularly in light of pressing proposals included in the development of BDCP.

References

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Appendix 1: Model Needs

Near-term

- Updated and maintained bathymetric and topographic (land surface elevation) data bases for the Delta and Bay, and expansion of these data bases to allow for improved ability to model water levels, flows, and salinities under conditions of sea-level rise and island flooding
- Continued improvement of 1-D models, especially to develop more accurate methods to parameterize 3-D dispersive processes in these models. This process will include integration and comparison of large-scale observations and numerical studies
- Better connection of Delta hydrodynamic models with upstream water management models
- Guidance for project managers on the roles, insights, and limitations of each of the available models for policy, planning, and management purposes
- Collection of 3-D tracer datasets (field data) for the establishment and validation of transport mechanisms for various scalars important within the Delta

Intermediate

- More accurate simulations of salinity for the entire Bay-Delta estuary that include better parameterization of dispersive mixing processes
- Improved accounting for the effects of in-Delta agricultural water use and drainage on salinity and other aspects of Delta water quality
- Expanded development of the capacity to model additional variables such as temperature, turbidity, residence time, nutrients, sediment, disinfection by-product precursors, toxics, phytoplankton and particles, including particles with behavior to better represent fish in Delta modeling and management
- Continued development of visualization tools for displaying modeling outputs that assist in communicating the results from modeling studies, and the development of pre- and post-processing tools that make models easier to use

Long-term

- Greater computational efficiency of multi-dimensional (hybrid) modeling systems to support ambitious Delta planning efforts requiring many runs in relatively short spans of time
- Improved methods to represent shoreline irregularities in multi-dimensional models, including underwater boundary representations in layered 3-D models
- New model features that make it easy to change the scales of numerical grid resolution within the Delta from coarse to fine scales, and that allow change in the dimensionality of a code as needed from 1-D, to 2-D, or to 3-D (so-called hybrid models)
- Improved real-time modeling capabilities to assist in real-time decision making

Appendix 2: Effective Long-term Modeling Program Needs

Longer-term responsibilities for the CALFED Science Program and the community of Bay-Delta modelers include elements of education, evaluation, development, licensing, research, and regular peer-review as part of a commitment to establishing and maintaining a state-of-the-art group of model developers, users, and interpreters. These elements are often discussed within the Bay-Delta modeling community, and there is broad-based support for collaboration and coordination for longer-term model and modeler improvement. Commonly, however, shorter-term priorities consume available expertise and money, and coordination among efforts between agencies with competing mandates is difficult without dedicated effort and funding. For these reasons, we recommend development of a collaborative, integrated program dedicated to advancing Delta modeling capabilities. We welcome management input and are ready to respond to calls for real progress and real work given real management and fiscal support.

By agreeing on the most appropriate directions for expanding existing modeling capabilities, our proposed program will permit the development of intermediate products while working toward longer-term objectives. We recommend that the proposed program include the following:

- Use of the diverse model and data development talents and capabilities already existing in California's agencies, universities, and consulting firms
- Establish community-wide 2-year, 5-year, and 10-year goals for strategic model development
- Leadership that maintains a consistent application-oriented scientific perspective and maintains focus on achieving strategic modeling goals (2-yr, 5-yr, 10-yr)
- Requirement of product completion according to 2-, 5-, and 10-year schedules to satisfy near-term modeling needs
- Proper mathematical verification of model codes and calculations, field testing of models, and peer-review of model algorithms and documentation
- An external review committee to provide outside scientific advice, oversight, and quality assurance, drawing on expertise from other estuaries
- Model codes and documentation made freely available in the public domain
- Identification of a caretaker of model codes and documentation
- Programmatic investment of $3 million/year for 5 years to support these recommendations

This modeling program would generate tools and products useful for a variety of applications: long term policy, planning, and regulatory decisions for the Management and Resources Agencies (CDWR, USBR, CDFG, USFWS, and NMFS), the State Water Resources Control Board, local agencies (particularly CCWD and Delta water districts), and other Federal agencies (USACE, USGS, and USEPA); real-time operations (by CDWR, USBR, CCWD, and local Delta water agencies); support for improved ecological modeling; support for operations and planning models; and support for improved understanding of Delta water quality, transport, flooding, and flows. The State Water Resources Control Board, through its mandated data collection for the IEP, can mandate changes in data collection to support this effort without undue increase in data collection budgets.

Appendix 3. Background on common operation and hydropower models

Operation Modeling

Almost all major rivers flowing into the Delta are controlled by large reservoirs in the foothills where the rivers enter the Central Valley. Traditionally the responsibility for meeting Delta requirements has been assigned to the major foothill reservoirs of the CVP (Trinity, Shasta, Folsom, New Melones) and SWP (Oroville), with lesser requirements from other major foothill reservoirs.

The CalSim II operations planning model for the CVP and SWP includes these reservoirs as well as the CVP/SWP project Delta export facilities and some other, smaller projects throughout the Central Valley and the Delta (except the Tulare basin). While having known limitations the CalSim II model is currently the large scale operations model being used in almost every major water supply project affects the Delta.

The CalLite model is a model of the CalSim II model. It is designed to be easier to use with a user interface, to run faster that CalSim, and to produce results similar to CalSim. Because CalLite's user interface, it can only simulate changes to specific operational parameters included in the model. Incorporation of these changes often requires CalSim simulations be performed which can then be used to guide modification of the CalLite interface.

Without knowing the specific questions to be addressed, the CalSim II model is typically more appropriate for modeling highly modified or new parameters, facilities, regulatory requirements, or operational rules. CalLite, after appropriate modifications if required, is used for repetitive, simulations with parameter modifications that can be made through the user interface. Several external reviews have been completed of CalSim II (Ford et al. 2006; Ferierra et al 2004, 2005; Close et al. 2003).

A variety of other system operations models have been developed for planning purposes. These include various applications of WEAP simulation, which emphasizes integration of hydrology and water demands. Several local agencies have stand-alone simulation models using various software platforms. Spreadsheet models also are common for operations planning simulation, even for large projects, both as stand-along models and for examination of small changes to the system perturbing base CalSim model results. Optimization modeling is widespread for hydropower operations above the foothill reservoirs, such as PG&E's SOCRATES model. For water supply, optimization models have so far remained largely restricted to academic studies, particularly CALVIN, although some of these have significantly informed policy discussions of climate change, the Delta, and infrastructure options.

Hydropower Modeling

Hydropower modeling has traditionally included the CVP/SWP system as they are the major focus of the CalSim II based operational modeling, and because they are major generators and users of hydroelectric power in California. The CVP is a net generator of power and the SWP is a net user of power.

Hydropower modeling of the CVP/SWP projects is done with two Excel spreadsheet based CalSim II post-processors, LongTermGen for the CVP and SWP Power for the SWP. The spreadsheets read monthly water operation data from CalSim II output and compute the energy production and usage of the project at their reservoirs, Delta export facilities, and throughout their distribution systems based on the unique generation or pumping characteristics at each facility. The computation simulates on and off peak operations by maximizing generation during peaking hours and pumping during off peak hours to maximize revenue and minimize costs.

Plexus is not technically a hydropower model, but a power market modeling tool. Hydropower facilities can provide several benefits other than energy generation (ancillary services) because of hydropower's unique characteristics to respond very quickly to changes in power market or grid conditions. There are implementations of Plexus, and other similar tools, to the power market in California. This type of model is useful in adjusting operations to maximize the overall value of hydropower facilities including any ancillary services. The major CVP/SWP facilities are operated for water supply and regulatory requirements first and hydropower second. This lack of flexibility limits the ability of the projects to re-operate to maximize ancillary services, and limits, but not eliminates the utility of this type of analysis.

Most of the many hydropower projects above the foothill reservoirs are operated by various proprietary optimization models, with additional software being used for hydrologic and power marketing. The effects of Delta regulations on these higher-elevation reservoirs are usually dampened considerably by the effects of usually much larger primarily water supply reservoirs downstream.

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